NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF:

March 27, 1971

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General
Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned
U.S. Patents in STAR

In accordance with the procedures contained in the Code GP to Code USI memorandum on this subject, dated June 8, 1970, the attached NASA-owned U.S. patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No.	:	3,349,814
Corporate Source	:	Avco Corporation 201 Lowell Street Wilmington, Massachusetts
Supplementary Corporate Source	:	
NASA Patent Case No.:		XMS-02009

Please note that this patent covers an invention made by an employee of a NASA contractor. Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of Column No. 1 of the Specification, following the words ". . . with respect to an invention of. . . ."

Gayle Parker

Enclosure:
Copy of Patent

FACILITY FORM 602

N71-20834	
(ACCESSION NUMBER)	(THRU)
6	00
(PAGES)	(CODE)
	33
(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

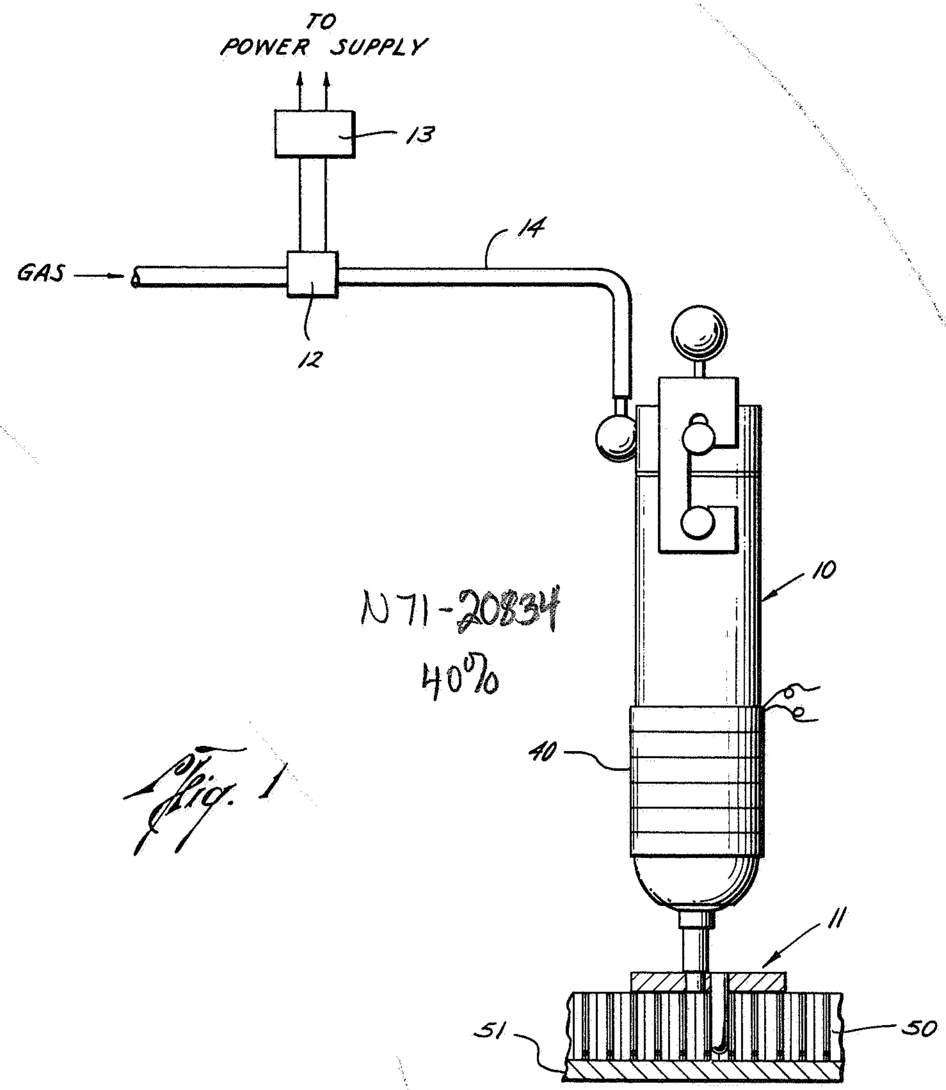
N71-20834

Oct. 31, 1967 JAMES E. WEBB 3,349,814

ADMINISTRATOR OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

METHOD AND APPARATUS FOR MAKING A HEAT INSULATING AND ABLATIVE STRUCTURE

Filed May 12, 1965 3 Sheets-Sheet 1



N71-20834
40%

Fig. 1

Robert W. King
Roy W. West, Jr.
INVENTORS

BY [signature]
Marvin F. Matthews
ATTORNEY

1200

Oct. 31, 1967 JAMES E. WEBB 3,349,814
ADMINISTRATOR OF THE NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION
METHOD AND APPARATUS FOR MAKING A HEAT
INSULATING AND ABLATIVE STRUCTURE
Filed May 12, 1965 3 Sheets-Sheet 2

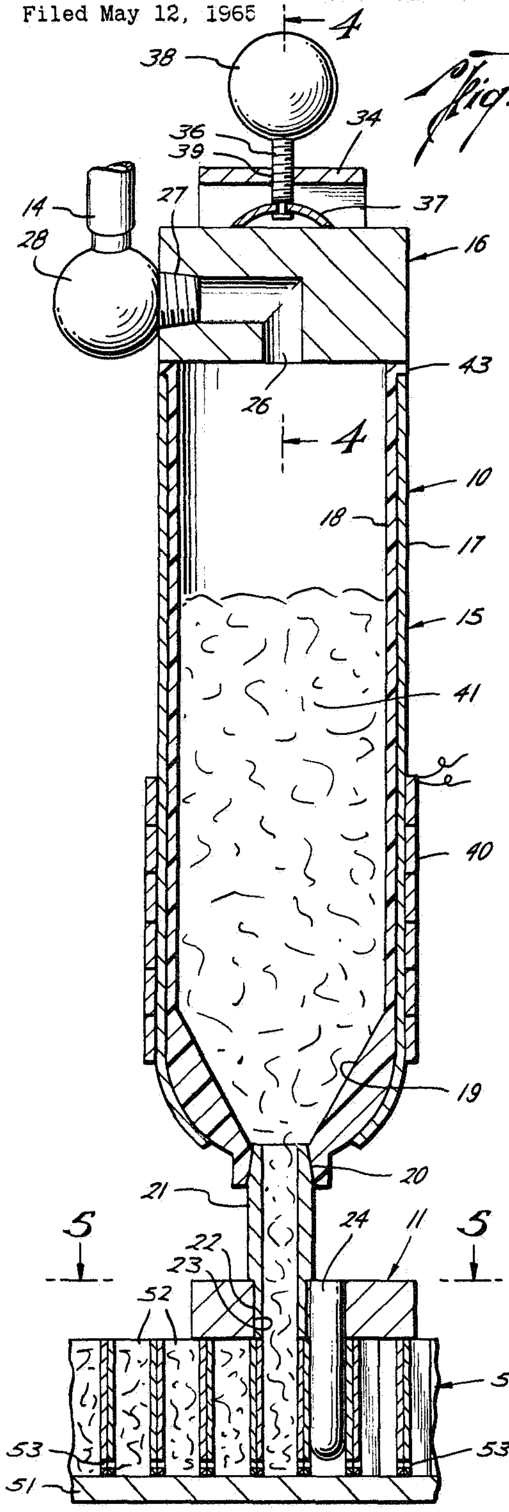


Fig. 2

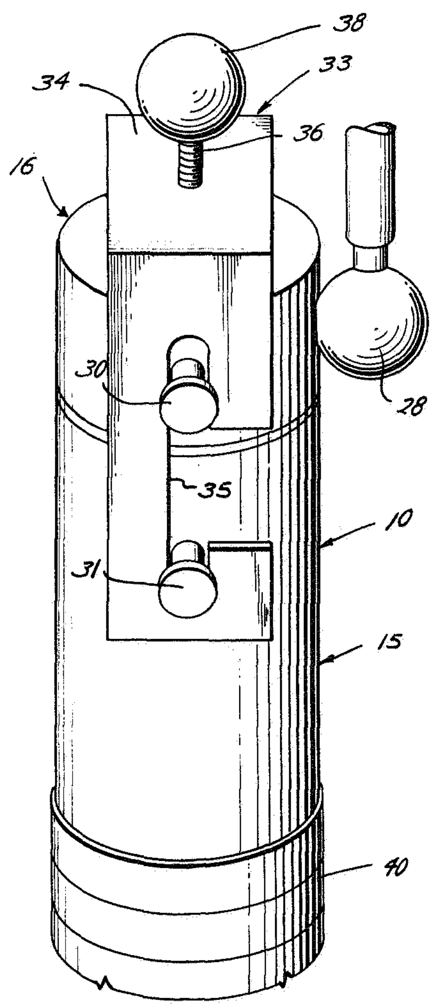


Fig. 3

Robert W. King
Roy W. West, Jr.
INVENTORS

BY
Marvin F. Matthews
ATTORNEY

Fig. 4

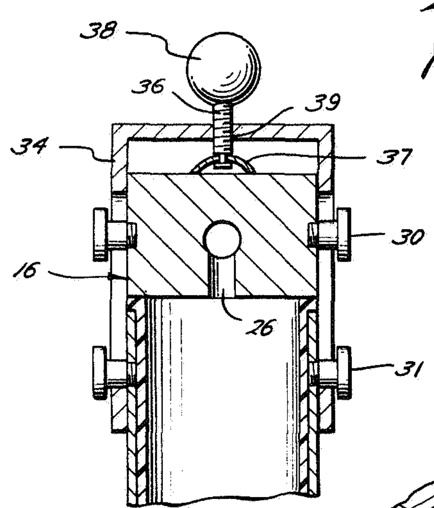


Fig. 5

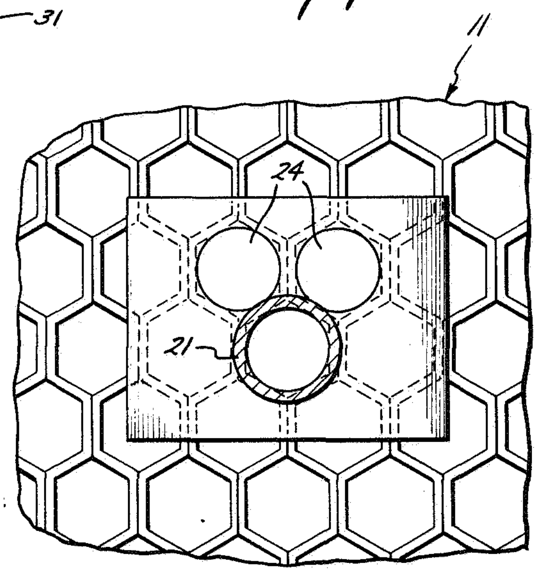
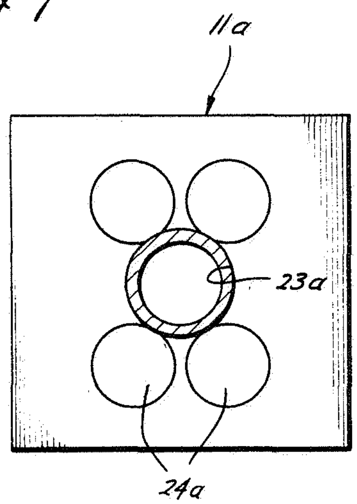


Fig. 6



Robert W. King
Roy W. West, Jr.
INVENTORS

BY [signature]
Marvin F. Matthews
ATTORNEY

3,349,814
METHOD AND APPARATUS FOR MAKING A HEAT INSULATING AND ABLATIVE STRUCTURE

James E. Webb, Administrator of the National Aeronautics and Space Administration with respect to an invention of Robert W. King and Roy W. West, Jr.

Filed May 12, 1965, Ser. No. 455,352
5 Claims. (Cl. 141—5)

ABSTRACT OF THE DISCLOSURE

Method and apparatus for uniformly filling an open celled heat shield matrix having a plurality of honeycomb like cells with a fibrous, highly flow-resistant insulating material. The gun containing said material is positioned over the cell to be filled by means of a plate having pins which fit into and support the adjacent cells of the matrix. The material is carried into the cell by gas which is supplied under pressure to the gun. After the material is deposited in the cell, the gas is exhausted from a venting opening in the lower end of the cell.

The invention described herein was made in the performance of work under a NASA contract and is subject to the provision of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85–568 (72 Stat. 435; U.S.C. 2457).

This invention relates to a method and apparatus for fabricating a heat insulating and ablation structure and more particularly relates to a method for the uniform filling of small diameter cavities with a fibrous, highly flow-resistant insulating material.

A tremendous amount of heat is generated when a spacecraft leaves orbital flight and reenters the earth's atmosphere. Some means of protecting the body of the spacecraft from this heat must be provided or else the craft will readily catch fire and burn. One highly successful means consists of attaching a structure having high heat insulative and ablative properties (commonly called a heat shield) to the leading edge of the craft to absorb, radiate, and ablate the reentry heat away from the body of the craft. In order for such a structure to perform satisfactorily, it must be light in weight and must possess certain properties which include, among others, the following: ability to produce large volumes of gas upon decomposition to thicken the boundary layer and thus reduce heat input from the boundary layer to the ablating surface; a high surface emissivity to increase the amount of heat dissipated by re-radiation; a low thermal conductivity to reduce heat transfer to the back side structure and to dissipate heat by storage.

However, most known materials having the above characteristics have little structural integrity when exposed to extreme heat conditions such as those encountered upon reentry. This makes the use of such materials by themselves undesirable, and in order to successfully use these materials a special structural base is required. Such a structural base is one formed of a substrate having a nonmetallic honeycombed matrix bonded thereto. The desired ablative materials, upon being filled into the cells of this honeycombed matrix, have been found to exhibit the high structural integrity required for the reentry stage of the spacecraft.

However, since the cells of the honeycomb are very small in cross-sectional area (3/8″ hexagonal honeycomb) as compared to their depth 2¼″ deep), severe problems exist in the uniform filling of these cells when highly viscous ablative material is used as a filler. This is especially true when the ablative material contains large quantities of fibrous or other solid material. These materials, such as ¼″ chopped silica (Refrasil) fibers, have a tendency to "bridge" across the small cells and seriously restrict the flow of material into the cells. This bridging causes some of the cells to be only partially filled, and such partial filling is highly detrimental to the successful operation of heat ablative structures such as the one described above. Before the present invention, each cell of the honeycomb had to be individually filled, compacted, checked, partially refilled, and compacted again until it was certain that each cell was completely filled. Such an extensive procedure makes this type of filling process both expensive and unduly time consuming.

The present invention provides a relatively quick and reliable method and apparatus for filling the small cells of a honeycomb with a semi-solid material having a fibrous texture which insures a complete and uniform filling of each cell. The filler material is placed in a filling gun which has a nozze at the lower end thereof, which in turn is accurately positioned over the cell to be filled by means of a positioning plate. This plate which receives the nozzle of the gun, has locator pins thereon which fit into empty adjacent cells of the honeycomb to properly align the nozzle. A timed burst of air or other gas is injected into the gun whereby the gas travels downward through the porous material and out the nozzle of the gun, carrying with it the material into the cell. The gas exhausts from the cells through small holes in the lower portion of the cell walls, said holes being provided therein at the time of manufacture. The ablative material which is too dense to flow through these holes will be carried to the bottom of the cells and deposited there. Since the material is positively carried to the bottom of the cell, "bridging" is eliminated and the complete filling of each cell is assured. The plate is then repositioned to fill another cell and the process is repeated until all the cells are filled. The length of time that is necessary to inject gas into the gun in order to completely fill a cell is easily determined during the filling of the first few cells, and through the use of automatic timer the same amount of gas is automatically injected into the gun for the filling of each cell. This uniform injection of gas insures that each cell will be uniformly filled. The present invention has proved highly successful for filling honeycomb matrices in the manufacture of heat shieds where such uniform filling is critical.

The invention will be better understood by referring to the drawings in which like numerals identify like parts in different figures and in which:

FIG. 1 is a schematic view, partially in section, of the apparatus used in carrying out the invention;

FIG. 2 is a vertical sectional view of the filling gun in accordance with the invention;

FIG. 3 is a perspective view of the filling gun of FIG. 2 broken away;

FIG. 4 is a vertical sectional view of the filling gun taken along the plane of line **4—4** of FIG. 2 and being reduced in scale;

FIG. 5 is a sectional view taken along the plane of line **5—5** of FIG. 2; and

FIG. 6 is a top view of a modified form of the positioning plate in accordance with the invention.

As shown in FIG. 1, the apparatus is comprised of filler gun or container **10**, positioning plate **11**, electrically operated three-way valve **12**, electric automatic time switch means **13** connected to valve **12**, flexible tubing **14** connecting valve **12** to gun **10**, and an air or other gas supply source (not shown) connected to valve **12**. A more detailed discussion of each of these elements and the purposes thereof are sent out below.

Filler gun **10** comprises a barrel portion **15** and a head

portion 16. Barrel 15 has an outer metal jacket 17 and an inner plastic liner 18. Jacket 17 is open at its lower end and liner 18 extends therethrough as clearly shown in FIG. 2. Two lock pins 31, the purpose of which is set forth below, are diametrically secured near the upper end of jacket 17. Liner 18 is tapered at its lower end 19 to provide streamline flow therefrom and has a flange 43 at its upper end which extends outward over the top edge of jacket 17 to serve as a sealing means between barrel 15 and head 16 when they are assembled.

The opening 20 at the lower end of liner 18 is tapered to receive nozzle 21 which is wedge fitted therein. The lower portion 22 of nozzle 21 is recessed so that it can be slip-fitted in opening 23 of positioning plate 11. The connection between nozzle 21 and plate 11 is by friction only, whereby the nozzle can be rotated with respect to plate 11 and can be easily removed therefrom when desired. Plate 11 has a plurality of locating and support pins 24 (see FIG. 5) attached thereto in a predetermined pattern. These pins are shown as being press-fitted into openings in the plate, but it should be recognized that any other suitable means, such as welding, could be used to attach the pins to the plate without in any way affecting the function of the plate. The purpose of the plate and support pins will be explained below. An electrical heating tape 40 is wrapped around the lower end of jacket 17 to heat the gun when desired, as will be more fully explained in the discussion below.

Head 16 has an L-shaped passage 26 therein with one end 27 threaded to receive swivel fitting 28 which in turn is connected to flexible tubing 14. Head 16 also has two guide pins 30 mounted diametrically opposed thereon (see FIG. 4). Clamp 33, which is used to secure head 16 to barrel 15, comprises a C-shaped member 34 which has a slot 35 in each leg thereof. These slots, as shown in FIGS. 3 and 4, cooperate with lock pins 31 on jacket 17 and guide pins 30 on head 16. A screw 36 having a washer 37 rotatably mounted at one end and handle 38 affixed at the other, is threaded through opening 39 in member 34.

To assemble gun 10, liner 18 with nozzle 21 attached is placed in barrel 17 and filled with the desired fibrous filler material 41. Next, head 16 is positioned on barrel 15 with pins 30 and 31 in axial alignment. Clamp 33 is placed onto pins 30 and 31, as shown in FIG. 3, with washer 37 resting on head 16. Handle 39 is rotated to thread screw 36 downward relative to member 34 to pull the member 34 upward to engage lock pins 31. At the same time screw 16 exerts a downward force through washer 37 on head 16 to compress flange 43 of liner 18 to insure an airtight connection. Although pins 30, 31, and clamp 33 have been shown as the means of joining head 16 to barrel 15, it should be understood that any other suitable connecting means could be used without departing from the invention.

Once gun 10 is filled and assembled, flexible tubing 14 is connected at one end to swivel fitting 28 and at the other end to a solenoid operated three-way valve 12 (see FIG. 1). Valve 12 is normally in position to exhaust the interior of gun 10 to the atmosphere, but upon application of electric current to the solenoid, the valve will move to a position connecting the interior of gun 10 to a compressed air or other gas source (not shown). The current for actuating valve 12 is supplied through electric automatic time switch means 13 which can be set to supply current for various desired lengths of time for a purpose explained below.

To fabricate a heat shield in accordance with the present invention, a non-metallic honeycombed matrix 50 is bonded or otherwise secured to metal substrate 51. The cross-sectional shape of cells 52 is that of a ⅜″ hexagon, and the cells are approximately 2¼″ in depth. Small holes 53 are provided in the walls of cells near their lower ends at the time of manufacture or at any time before the matrix is bonded to the substrate.

Next, positioning plate 11 is placed on matrix 50 so that support pins 24 extend into and support the cells immediately adjacent the cell which is to be filled. The number of pins 24 may vary, depending upon the area of the matrix which is being filled, i.e., more pins would be required in filling the center area of the matrix than would be required in filling along the edge thereof. As seen in FIG. 5, plate 11 has two pins 24, while in FIG. 6 plate 11*a* has four pins 24*a*. Once the plate is in position, nozzle 21 of gun 10 is slipped into hole 23 on the plate and is thereby positioned directly over the cell to be filled, due to the construction of plate 11. Not only do pins 24 accurately locate the nozzle over the cell, but these pins also support the walls of the adjacent cells and prevent rupture or bulging of these cell was which might otherwise occur from excessive air pressure during filling operations.

With the gun 10 loaded with fibrous filler material 41, and with nozzle 21 properly positioned in plate 11, automatic time switch means 13 is actuated to supply current to solenoid valve 12 to move same to an open position with respect to a compressed gas source so that a timed burst of gas is delivered to the gun 10. This gas will pass through passage 26 in head 16 and into liner 18. Due to the fibrous nature of filler 41, the gas will not act directly on the top thereof to force it from the liner, as might be expected, but instead travels through the inherent passages in the fibrous material, out nozzle 21, and into the cell of matrix 50. This gas carries the fibrous material with it and deposits it within the cell, while the gas itself exhausts through the small holes 53 in the cell walls and out the empty adjacent cells. By means of automatic time switch means 13, the gas will be allowed to flow into gun 10 for that length of time which has been predetermined as necessary to insure complete filling of the cell. This time will vary between different honeycomb matrices, of course, depending on cell size, filler material, etc. When the desired time has elapsed, automatic time switch means 13 will shut off, thereby deactivating valve 12 which then returns to its normal position to exhaust gas from gun 10. The plate 11 and gun 10 can then be moved to a new position and the operation is repeated. Due to its high resistance to flow, the filler material will cease to flow when the gas pressure ceases and will not spill or exit from the gun during the movement of the gun.

A typical example of a filler material which is used for filling small celled honeycomb matrices in accordance with the present invention is one which is comprised of phenolic micro-balloons, ¼″ chopped Refrasil fibers, and ¼″ milled "E" glass mixed with an epoxy system as a binder. Although this material is highly porous, it must be heated to 160°–180° F. before it will flow in accordance with the above disclosed method. Electrical tape 40 is actuated to heat gun 10 when such material is used. Also, the gas used to carry this material may be preheated if necessary by including a heating element (not shown) in the gas line leading to valve 12.

It is obvious from the above description that a simple and effective method is provided for uniform filling of a small celled matrix with high flow-resistant, fibrous material. As stated above, this is of vital importance in the manufacturing of heat shields for space reentry vehicles where partially filled cells of such a matrix could easily mean disaster since such cells provide paths through the heat shield along which heat can travel to the substrate, thereby causing excessive heating of the spacecraft. Also, this method allows the cells to be filled regardless of their orientation. That is to say that cells can be filled in a vertical position, horizontal position, or even if they are upside down, due to the fact that the material is carried by the gas and that the material, being high resistant to flow, will stay in place once it has been deposited in the cell.

It should be understood that the foregoing disclosure

relates only to the preferred embodiment of the invention, and that it is intended to cover all changes and modifications therein which do not constitute departure from the spirit and scope of the invention.

What is claimed and desired to be secured by Letters Patent is:

1. The method of filling a cell of honeycomb matrix to a uniform density with a highly flow-resistant, fibrous filler material comprising:

placing a positioning plate over the cell to be filled, said plate having pins thereon which fit into and support the cells adjacent to the cell to be filled;

positioning the outlet nozzle of a filler gun containing said fibrous filler material therein in communication with the cell to be filled by placing said nozzle in an opening on and through said positioning plate;

applying gas under pressure to the interior of the gun and onto said filler material whereby said gas passes downward through the passages which are inherently present in the fibrous material and into the cell, carrying said material with it into the cell;

exhausting said gas from the cell from near the lower end thereof after it has carried the material into the cell;

ceasing the supply of gas to said gun upon complete filling of said cell; and

venting said gun to the atmosphere.

2. The method of filling a cell of a honeycomb matrix to a uniform density with a highly flow-resistant, fibrous filler material comprising:

positioning a container of said filler material in direct communication with the cell to be filled while supporting the walls of the cells adjacent the one to be filled;

applying a predetermined amount of gas under pressure to said container whereby said gas passes through the passages which are inherently present in the fibrous material and into the cell to be filled, carrying said material with its into the cell;

exhausting said gas from the cell near the lower end thereof after it has carried the material into the cell; and

releasing the pressure from said container after the predetermined amount of gas has been supplied thereto.

3. The method of filling a cell of a honeycomb matrix to a uniform density with a highly flow-resistant, fibrous filler material comprising:

positioning a container of said filler material in direct communication with the cell to be filled while supporting the walls of the cells adjacent the one to be filled;

applying gas under pressure to said container whereby said gas passes through the passages which are inherently present in the fibrous material and into the cell to be filled, carrying said material with it into the cell;

exhausting said gas from the cell near the lower end thereof after it has carried the material into the cell;

ceasing the flow of gas to the container after the cell is filled; and

venting said container to the atmosphere.

4. The method of filling a cell of a honeycomb matrix as set forth in claim 3 wherein the flow of gas to the container is ceased automatically after a predetermined length of time.

5. An apparatus for filling a cell of an open celled matrix with a fibrous, heavily viscous material comprising:

a container adapted to receive said fibrous filling material, said container having a first opening at one end and a second opening at its other end;

a nozzle secured at one of its ends in said first opening of said container;

a positioning plate having an opening therethrough, the other end of said nozzle being rotatably positioned in said opening of said plate;

positioning pins fixedly secured to said plate, said pins adapted to fit into and firmly support the cells of the matrix adjacent the cell to be filled, said pins being arranged on said plate whereby said nozzle will be properly positioned over the cell to be filled when said pins are in place; and

means attached to said second opening in said container for supplying gas under pressure to said container.

References Cited

UNITED STATES PATENTS

2,360,914	10/1944	Van Ness	141—326
3,063,477	11/1962	Vogt	141—5
3,172,604	3/1965	Brock	222—193 X
3,281,019	10/1966	Curry	222—193 X

SAMUEL ROTHBERG, *Primary Examiner.*

E. J. EARLS, *Assistant Examiner.*